CS 348: Computer Networks

- LLC-ARQ; 2\textsuperscript{nd} Aug 2012

Instructor: Sridhar Iyer
IIT Bombay
Recall: Delay X Bandwidth Product

- Relative importance of bandwidth and delay
  - Small message: 1ms vs 100ms dominates 1Mbps vs 100Mbps
  - Large message: 1Mbps vs 100Mbps dominates 1ms vs 100ms

- Example:
  - 100ms delay and 45Mbps bandwidth
    => 560 KB of data in the pipe
We will move from a single link to ...

Direct Links

- Point-to-point connectivity

Shared Links

- Multiple access network
Today's class discussion

- Having seen the concepts in PHY, we will get into the Link layer (MAC and LLC), also known as Layer 2.

- What should be the concerns of the Link layer?
- What services should Link layer provide?

- Let us quickly put some answers on the board!
Data link layer

Controls a single physical link
Service interface to network layer
Data link functions

• Medium access control
  • Regulating multiple access to the medium

• Logical link control
  • Grouping of bits into frames
  • Dealing with transmission errors
  • Regulating the flow of frames
Logical link control (LLC)

- Framing (start and stop)
- Error Detection
- Error Correction
- Flow Control (optimal link usage)
- Examples: HDLC, LAP-D, PPP
Design Issues - ACKs

- Providing ACKs in this layer is an optimization not a requirement.
- Transport layer can very well provide reliable service

- Question to think about: In what cases should ACKs be implemented in link layer?
Example Frame Format : HDLC
Framing

- Starting and ending flags, with *bit stuffing*
  - each frame begins and ends with a special bit pattern, 01111110
  - allows data frames to contain arbitrary number of bits
  - allows character codes with arbitrary number of bits per character

- Self-study question: What is bit stuffing?
Bit level error detection

Single-bit, multi-bit or burst errors introduced due to channel noise.

● Detected using redundant information sent along with data.

● Full Redundancy:
  ● Send everything twice
  ● Simple but inefficient
Error detecting codes

- error-detecting codes: include enough redundancy to allow receiver to detect error
- more efficient and preferred solution
  - parity check
  - cyclic redundancy check (CRC or polynomial code)
  - checksum

- More on this later!
Frame level error correction

• Problems in transmitting a sequence of frames over a lossy link
  • frame damage, loss, reordering, duplication, insertion

• Two Solutions:
  • Forward Error Correction (FEC)
    − Use of redundancy for packet level error correction
Frame error & flow control - ARQ

- Problems in transmitting a sequence of frames over a lossy link
  - frame damage, loss, reordering, duplication, insertion

- Automatic Repeat Request (ARQ)
  - Detection: Sequence numbers, Timeouts
  - Correction: Use acknowledgements and retransmission
Sequence numbers

• In each header
• Incremented for non-retransmitted packets
• Sequence space
  • set of all possible sequence numbers
  • for a 3-bit seq #, space is \{0,1,2,3,4,5,6,7\}
Using sequence numbers

• gap in sequence space allows receiver to detect loss
  – e.g. received 0,1,2,5,6,7 => lost 3,4

• Receiver sends ACKs which carry cumulative seq #

• if no ACK for a while, sender suspects loss
  • need to choose timeout interval
Timeouts

• Set timer on sending a packet
• If timer goes off before ACK, resend

• How to choose timeout value?
• We expect a reply in about one round trip time (RTT)
Timeout schemes

• Static scheme
  • know RTT \textit{a priori}
  • timer set to this value
  • works well when RTT changes little

• Dynamic scheme
  • measure RTT
  • timeout is a function of measured RTTs

• More on this later!
Retransmission Schemes
Stop and Wait ARQ

- Sender waits for ACK after transmitting each frame.
- Receiver sends ACK if received frame is error free.
- Sender retransmits frame if ACK not received before timer expires.
Stop and Wait ARQ

- Simple to implement but may waste bandwidth;
- Example: 1.5Mbps link $\times$ 45ms RTT = 67.5Kb (8KB).
  - Assuming frame size of 1KB,
  - stop-and-wait uses one-eighth of the link's capacity.
  - Sender should be able to transmit up to 8 frames before having to wait for an ACK.
Stop-and-Wait ARQ

1. View the link:
http://oscar.iitb.ac.in/onsiteDocumentsDirectory/StopAndWaitARQ/StopAndWaitARQ/index.html

2. Play with the various settings in the animation till you are able to answer questions like: "What is the difference between the frame error case and ack error case?" There are also self-test questions at the end of the animation.